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# DISORIENTATION PHENOMENA IN NAVAL HELICOPTER PILOTS

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Naval Aerospace Medical Research Laboratory
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13. ABSTRACT


The incidence of pilot disorientation in fixed and rotary wing aircraft has been previously investigated, but special orientation problems of naval helicopter pilots engaged in operations at sea and landing on moving platforms have not been previously reported.

A questionnaire concerning disorientation was answered anonymously and individually by 104 active naval helicopter pilots. Fifty-six percent indicated one or more episodes of severe disorientation and 8.5 percent indicated having experienced severe disorientation five or more times while piloting helicopters. A number of factors conducive to disorientation were identified. Some precipitating factors appear to be specific to operations over water or over a moving deck, although some of these may well have their counterparts in special operations over land. Other factors are common to land- and sea-based operations and some are common to fixed-wing as well as rotary-wing aircraft.

A number of potential countermeasures for various precipitating factors are discussed.




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# DISORIENTATION PHENOMENA IN NAVAL HELICOPTER PILOTS

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## SUMMARY PAGE


### THE PROBLEM

The incidence of pilot disorientation in fixed and rotary wing aircraft has been previously investigated, but special orientation problems of naval helicopter pilots engaged in operations at sea and landing on moving platforms have not been previously reported.

### FINDINGS

A questionnaire (Appendix A) concerning disorientation was answered anonymously and individually by 104 active naval helicopter pilots. Fifty-six percent indicated one or more episodes of severe disorientation, and 8.6 percent indicated having experienced severe disorientation five or more times while piloting helicopters. A number of factors conducive to disorientation were identified. Some precipitating factors appear to be specific to operations over water or over a moving deck, although some of these may well have their counterparts in special operations over land. Other factors are common to land- and sea-based operations, and some are common to fixed-wing as well as rotary-wing aircraft.

The most common phenomenon reported by respondents was "the leans"(91 percent), and the most common conditions reported as leading to disorientation were 1) low altitude hover over water at night (81 percent); 2) reflection of anti-collision lights on clouds, fog, or spray (70 percent); 3) transitions from IFR (instrument flight rules) to VFR (visual flight rules) and vice versa (62 percent); 4) misinterpretation of relative position and movement during night approach to ship (58 percent); and 5) head movement during bank and turn (56 percent). Further down the list but still a surprisingly high figure (45 percent) was inability to read instruments due to vibration. A number of potential countermeasures for various precipitating factors are discussed.



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## INTRODUCTION

This study was undertaken in order to elucidate the frequency and types of spatial disorientation experienced by naval helicopter pilots. The helicopter has become increasingly prominent in antisubmarine warfare (ASW), search and rescue (SAR), and as a general utility platform in modern naval operations. This prominence is reflected in the percentage of operational naval aircraft which are helicopters, 18.7 percent in fiscal year 1973. This compares with 12.7 percent in fiscal 1963, and 7.4 percent in fiscal 1958 (12).

Disorientation continues to be a factor in the loss of crews and aircraft. A complete review of U. S. Naval Safety Center records encompassing the period between 1 January 1969 and 31 December 1973 disclosed a total of 23 naval helicopter mishaps in which the investigating flight surgeon reported pilot disorientation or vertigo as a definite or suspected factor. Fatalities occurred in 12 of these helicopter mishaps, totaling 29 deaths over the described 5-year period.

Disorientation in helicopters has been previously studied in Air Force and Army pilots (1,3-5,7,9). However, disorientation experienced by naval helicopter pilots, especially while engaged in operations at sea, has not been previously reported. In the setting of shipboard operations, the aviator is confronted with new factors conducive to disorientation, and often with fewer visual cues and more complex relative motion problems than land-based aircraft.

This study seeks to describe flight conditions in which disorientation is most likely to occur during shipboard helicopter operations. In addition, the role of the helicopter's aerodynamic properties and cockpit instrument layout is discussed as it may relate to pilot disorientation.

## PROCEDURE

### METHOD

A questionnaire, presented in Appendix A, was composed and distributed to a pool of approximately 190 active naval helicopter pilots; 104 questionnaires (55 percent) were completed individually and returned anonymously through squadron safety officers.

Disorientation was defined in instructions accompanying the questionnaire as "an incorrect or 'seat-of-your-pants' impression of the attitude, position, or movement of the pilot and/or aircraft relative to the horizon or other stable reference." The flight deck of a moving ship was considered a "stable reference." Vertigo was defined as "a sensation that the pilot or environment is spinning." Navigational error was not considered true disorientation.

The degree of disorientation was to be subjectively graded by the responding aviator as follows:

mild -- pilot felt disoriented and uncomfortable but always felt in control of the aircraft

moderate -- pilot felt disoriented and concerned and there may have been adverse effect on aircraft control

severe -- pilot felt disoriented, mentally stressed and/or there was definite interference with aircraft control

All questions applied only to experiences as pilot or copilot in helicopters. Fixed-wing experiences were specifically excluded.

Pilots involved in the survey were assigned to antisubmarine and utility squadrons at the time the study was taken. It is therefore expected that the results reflect heavily on antisubmarine and utility operations at sea. The majority of disorientation episodes reported occurred in Sikorsky H-3 helicopters.

## RESULTS

A list of factors and flight conditions which have been associated with disorientation in helicopters was presented in the questionnaire. Table I lists in decreasing order the percentage of 104 aviators reporting disorientation under each described circumstance, according to the aviator's recall, during his career as a helicopter pilot. Additional factors not listed in the questionnaire, but felt related to disorientation by the respondent, were elicited and are listed in Table II.

The aviators involved in the study had accumulated a total of over 98,000 helicopter flight hours, including over 20,000 actual or simulated instrument hours.

Of 104 pilots involved in the study, one (0.96 percent) denied any degree of disorientation. Thirty-seven (36 percent) reported situations where both pilots became disoriented simultaneously or during the same flight. Four (3.8 percent) had been involved in accidents as a consequence of disorientation.

When specifically queried about severe disorientation as described above, 34 (33 percent) denied any episode of severe disorientation as helicopter pilots, while 58 (56 percent) admitted one or more episodes of severe disorientation. Twelve pilots (11 percent) did not answer, and nine pilots (8.6 percent) had experienced severe disorientation five or more times.

As noted in Table I, the most common type of disorientation reported was "the leans." It is of interest that this phenomenon appears to be the most frequently encountered type of disorientation, exclusive of geographic disorientation, in both rotary and fixed-wing aircraft. "The leans" has remained the most frequently observed orientation problem for several decades regardless of aircraft type or performance capabilities (4).

Table I

Percentage of 104 Pilots Who Have Experienced Disorientation under Described Circumstances While Piloting Helicopters

| | | |
|---|---|---|
| 1. | Sensation of not being straight and level after bank and turn ("the leans") | 91 |
| 2. | Low altitude hover over water, night | 81 |
| 3. | Reflection of anti-collision light on clouds and fog outside the cockpit | 70 |
| 4. | Transitioning from IFR to VFR and vice versa | 62 |
| 5. | Misinterpretation of relative position or movement of ship during night approach | 58 |
| 6. | Head movement while in bank or turn | 56 |
| 7. | Landing on carrier or other aviation ship, night | 51 |
| 8. | Night transition from hover over flight deck to forward flight | 49 |
| 9. | Misperception of true horizon due to sloping cloud bank | 47 |
| 10. | Inability to read instruments due to vibration | 45 |
| 11. | Take-off from carrier or other aviation ship | 39 |
| 12. | Reflection of lights on windshield | 36 |
| 13. | Awareness of flicker of rotors | 35 |
| 14. | Misperception of true horizon due to ground lights | 33 |
| 15. | Fatigue | 32 |
| 16. | Distraction by aircraft malfunction | 29 |
| 17. | Formation flying, night | 25 |
| 18. | Misled by faulty instrument | 25 |
| 19. | Vibration | 24 |
| 20. | Misjudgment of altitude following take-off from carrier or other aviation ship | 21 |
| 21. | Going IFR in dust, snow, water, in low hover | 19 |
| 22. | Loss of night vision | 15 |
| 23. | Take-off or landing in strong cross winds | 13 |
| 24. | Symptoms of cold or flu | 11 |
| 25. | Low altitude hover over water, day | 10 |
| 26. | Formation flying, day | 8.6 |
| 27. | Low altitude hover over land | 6.7 |
| 28. | In-air refueling from moving ship | 2.8 |
| 29. | Self-treatment with over-the-counter drugs | 1.9 |
| 30. | Landing on carrier or other aviation ship, day | 0.96 |

Table II

Additional Factors Associated with Disorientation in Helicopters

| | |
|---|---|
| 1. | Perception of wind through cockpit side window while in hover or translational lift. |
| 2. | Flying into smoke flares |
| 3. | Task saturation |
| 4. | Wave motion interpreted as aircraft motion |
| 5. | Hot switch (crew change while rotors engaged) at night |
| 6. | Low altitude search pattern at night |
| 7. | Night launch from forward spots on flight deck |
| 8. | Lack of recent instrument flying |
| 9. | Relative immobilization by wet suit for prolonged periods |
| 10. | Communication difficulty (noise, poor radio discipline) |

Feelings of detachment or the "break-off phenomenon" (2,5) were not reported by this sample of helicopter pilots as leading to disorientation. Many pilots did report during interviews a sensation of being "suspended in space" while flying helicopters. However, no feelings of estrangement, detachment from the aircraft, or unreality as described by Benson (2) were elicited during interviews. This finding does not necessarily suggest inconsistency with Benson's observations, since his sample was not considered by him (2, p.944) as representative of a typical pilot population. The present data indicate that "break-off" is not a common problem in the Navy helicopter pilot.

An extremely prevalent type of disorientation in naval helicopter pilots, not previously described, occurs at night in a 40-foot hover over water while "dipping" sonar, a common submarine detection technique during which a sonar dome is lowered as much as 450 feet below the ocean surface. The following case narratives illustrate the problem:

Case 46. Helicopter type, SH-3D; mission, night ASW; weather, clear night, no moon; pilot hours, 1000. "In a night dip, cable angle became unstable"... (sonar dome in water drifted from position directly below the aircraft)..."I commenced a free stream recovery"...(immediate vertical ascent to retrieve sonar dome)..."I commenced my rate of ascent slowly and cautiously, but things shortly turned to worms. At about 200 feet, I noticed the aircraft spinning to the right. I ended up 90° off my original heading. At about 400 feet, I finally got squared away."

Case 63. SH-3H, night ASW, overcast, black night. "I was copilot flying dip and allowed the aircraft to drift off-heading in a 35 knot wind. Pilot took aircraft, stepped on rudder pedal to get back into the wind. As aircraft came right...I had sensation of spinning and rolling to the right and descending...noted 20 foot altitude and 20° nose up. Finally, pilot ...climbed out...we lost the (sonar) dome and stabilized on heading 180° from our last heading."

Case 67. SH-3, black night, ASW. "On night dip...copilot became established in a dip. I lowered my head to change a card on my kneeboard. Next thing I knew, my copilot said, 'You better take it.' I snapped head up and grabbed the controls...I could not bring the instrument console into focus...low altitude light was flashing and nose was above 10° up, we were backing down and losing altitude...(we) executed a free stream recovery."

Case 71. SH-3H, black night, ASW, 600 helo hrs. "In night 40 foot dip...I had control of aircraft...I was checking copilot's air speed indicator...head movement completely disoriented me, felt descent, climb, right and left wing low...initiated a free stream recovery."

Case 72. SH-3, night ASW, no moon or horizon. "In a night dip... (I) was trying to keep the aircraft into the wind...became confused as to where the wind was from...the indications of wind in windows and air speed indicator seemed to disagree...I added rudder pedal correction...but aircraft began to drift and the whole world began to spin...I gave the aircraft to the pilot."

Case 83. SH-3D, overcast night ASW, no horizon, 350 hrs. "In night dip, got sensation moving aft and sideways...mental stress...caused my scan to break down...passed thru 30 feet twice...passed control to pilot."

Several factors can be identified as conducive to disorientation in a night hover at sea. In essence, this is an instrument flight rules (IFR) hover at minimum altitude, in an oscillating, vibrating platform. Keeping the relative wind "on the nose" is crucial in order to maintain a stable hover directly over the sonar dome. Distraction from a continuous instrument scan in this configuration can and often does lead to severe disorientation (Case 67). Unless the pilot has disciplined himself to adhere strictly to instruments, he will apply control input in response to somatic sensations. For example, wind entering through the right cockpit window produces a subjective sensation that the aircraft is drifting right (Case 72), when in fact it may be in a stable hover.

Another factor which may disorient the pilot is a relative motion illusion which occurs in a low-altitude hover over water. The stage for this illusion is set when the helicopter's rotor wash causes a wake in the water which radiates away from the aircraft. Perception of waves moving away from the pilot may induce a sensation of backward motion, to which the pilot may respond with incorrect control input, thus placing the aircraft in an unusual attitude.

The importance of the anti-collision beacon reflection as a source of disorientation in helicopters has long been recognized (4,5). Reflection on clouds, fog, precipitation and salt spray, particularly at night, continues to be a very significant disorientation-inducing factor (see Table 1). Many experienced aviators turn off the forward rotator beacon to avoid becoming disoriented while flying through weather. Paradoxically, it is at night and in low visibility conditions that the anti-collision beacon performs its primary role.

The anti-collision light can also lead to visual illusions:

Case 78. SH-3, black night, ASW, no horizon, overcast. "In a 40 foot hover, copilot in the left seat reported fire in number one engine. (We) free-streamed to 300 feet and no indications (were noted) visually or inside the aircraft of fire. Went into a dip again...and copilot again reported fire in number one engine after (becoming established) in a hover. Reason: With low visibility and salt spray around the aircraft, the anti-collision light rotating and reflecting thru the copilot's window and on the aircraft made him...call a fire."

It is noteworthy that perception of rotor flicker, a classic form of disorientation in helicopters, was mentioned half as often as anti-collision light reflection as contributing to disorientation (see Table I).

The period of transition from instrument flight rules (IFR) to visual flight rules (VFR) and vice versa has been known to be a prime time for pilot disorientation (3), and 62 percent of pilots involved in this study experienced disorientation during that transition, confirming previous observations in both fixed- and rotary-wing operations (4). The percentage of pilots in this study reporting IFR/VFR transitions as a factor in disorientation is higher than percentages previously indicated (cf. 4, p. 709).

Because ship-based helicopters must land on an oscillating, moving deck, spatial orientation is often lost when the pilot fails to conceptualize his speed, motion, and attitude relative to the speed and motion of the ship. A common form of disorientation due to misjudgment of relative motion occurs during night approaches to aviation ships. As the aviator commences the approach, his reference may be a single light source which becomes discernible as several light sources as the aircraft nears the ship. At this time, the ship may still be turning into the wind in preparation to recover aircraft. As the ship turns, the relative position of deck and other discernible lights changes. The pilot may experience a total loss of reference and be unsure whether he is approaching from the bow, stern, or abeam. The closure rate is also frequently misjudged in the setting.

On the final approach phase at night, disorientation may occur as the aircraft is brought to a hover abeam the flight deck, matching the ship's course and speed. The helicopter then enters a maneuver termed a "steady heading side-slip," sliding in to its landing spot, while descending, in forward flight and slipping to the right. This maneuver, though complicated, rarely leads to disorientation when adequate visual cues are available. (Disorientation in daylight was reported by 0.96 percent of pilots, Table I.) However, at night, 51 percent of pilots have experienced disorientation executing this maneuver.

When the final landing phase is prolonged in heavy seas at night, disorientation may occur if the pilot "chases the flight deck" while it pitches and rolls. Also during this final phase of landing, the pilot shifts from IFR to VFR, his visual reference becoming the flight deck. Disorientation is also particularly apt to occur when the pilot is waved off from the final phase of a night landing. The pilot must turn and gain altitude and loses all visual reference, simultaneously shifting back to IFR.

For readily apparent reasons, disorientation in a night hover at sea is particularly hazardous. Other than "dipping" sonar, helicopters may be required to hover over water in marginal weather or at night while engaged in rescue operations. The hazards of night rescue hovers are illustrated below:

Case 39. SH-3, clear night, SAR, 800 hours. "On a night man-overboard call...I flew into smokes (dropped to mark the search area)...which hung in the area...I lost all reference to altitude and attitude. I pulled up when I saw the light in the water (at) 2-3 feet altitude...as soon as I cleared the smokes I reoriented myself."

Case 43. Helo type not given, clear night, 1200 hours. "I was copilot in a night SAR (mission)...we searched just aft of the ship... we were all looking for the survivor. At 40 feet and 30-40 knots, the pilot thought he saw the survivor and tried to slow down while looking over his right shoulder. The aircraft started backing down to the left and we passed through several smoke flares...(the) pilot never admitted vertigo, but I took the aircraft...we finally recovered completely from our vertigo at 1200 feet and 130 knots."

Case 65. SH-2, night, fog, 900 hours. "In a night 15 foot hover with hover lights on, (the) salt spray descending through the rotors gave me the appearance of descending into the water. Resulted in altitude variations up to 200 feet and back down...pilot in the left seat had the same sensation but recognized our descent...and took the aircraft."

Case 97. SH-3G, dark night, SAR, no moon, fog, 600 hours. "(We)... launched on a night man-overboard call...and were directed to a group of flares dropped by the ship...we used smokes to get our wind and descended to 150 feet...once in a hover we moved to the smokes...I was on gages being directed by the copilot...I began to experience disorientation due to the brightness (of flood lights) below me in contrast to the darkness of the sky around me. Disorientation lasted...3 to 5 minutes... and was felt by both pilots. Swirling smoke inside and outside the cockpit made it difficult to see the instruments. I waved off and returned to 150 feet."

Case 102. SH-3, night, SAR. "In a night plane guard pattern, we were ordered to investigate a strobe light someone threw off the side (of the ship). I was copilot...the pilot proceeded to enter a manual approach to a hover. I was watching outside the aircraft and the pilot developed a good case of disorientation without telling me. By the time I had realized what had happened we were upside down in the water."

It has been suggested that helicopters should be equipped with additional instrumentation and that perhaps changes in cockpit layout may reduce the frequency and severity of disorientation. This question was posed in the questionnaire, and the results are presented in Table III. Only 30 pilots (29 percent) felt additional instrumentation would be desirable. However, it was noted that those aviators who felt additional instrumentation was necessary were, as a group, more senior, with experience in both

## Table III

**Percentage of 104 Pilots Recommending Changes in Cockpit Instrumentation to Reduce Disorientation**

| | |
|---|---|
| Recommended additional instruments | 30 |
| No additional instrumentation recommended | 49 |
| Additional instrumentation detrimental | 5.7 |
| Did not answer | 16 |

## Table IV

**Cockpit Changes Recommended by Pilots in the H-3 Helicopter**

1. Reduce area of instrument scan by combining flight instruments (i.e., one display incorporating such instruments as VGI (Vertical Gyro Indicator), TACAN, CDI (Course Distance Indicator), and Turn and Bank Indicator).

2. White light rather than red.

3. Enlarge and relocate Vertical Speed Indicator.

4. SH-3H; OTPI (On Top Position Indicator) and navigator should be moved forward on center console.

5. SH-3A, D and G; remove turn and bank indicator from behind cyclic stick. SH3-H; remove vertical speed indicator from behind cyclic stick.

6. Add wind indicator sensitive down to 2-3 knots.

7. Place read-out radar altimeter on vertical gyro indicator.

8. Add flight director system to reduce scan.

9. Incorporate TACO (Tactical Air Coordinator) with adequate tactical navigation display in aircraft such as SH-3H.

fixed- and rotary-wing aircraft. Six pilots (5.7 percent) felt additional instruments would "clutter" the cockpit, cause a broader scan, and thus become a liability rather than an aid. It should be noted that changes suggested in cockpit instruments were made by pilots presently flying H-3 helicopters, although similar cockpit revisions can be equally beneficial in other type helicopters.

One deficiency frequently noted was the broadness of the scan in the H-3 cockpit while IFR at night during ASW missions which require the pilot to make continuous head movements to monitor flight and engine instruments in the forward instrument panel, and ASW instruments in the aft center console. In addition, some instruments are hidden behind the cyclic control stick, requiring the pilot to look around the stick. Many pilots felt that several flight instruments could be combined or relocated (Table IV). Specifically noted in questionnaires completed by several senior helicopter pilots was the observation that too often, helicopter instruments are drawn from "on hand" fixed-wing stocks not primarily designed for rotary wing aircraft.

Thirty-eight percent of the respondents indicated other helicopter characteristics conducive to disorientation, some of which are listed in Table V. An idiosyncratic problem in the H-3 helicopter is the fact that it hovers 4 degrees left wing low and 2 degrees nose up in still air, which some pilots felt may contribute to disorientation in an IFR hover. It is not clear whether this small departure from a level attitude is consistently perceptible by all aviators, but it does appear that most aviators can detect this variation.

The vibration level experienced during translational lift was felt to be excessive by some aviators. During translational lift, the aircraft transitions from forward flight into a hover, or vice versa. The vibrations produced in this phase of flight often blur the instrument panel, and the pilot may be unable to accurately read cockpit instruments for as long as 15 seconds. Since translational lift occurs at low altitude during the take-off and landing phases (i.e., during entry and departure from a hover), the pilot in IFR conditions may be momentarily deprived of an important source of spatial orientation at a critical phase of flight. Since a large component of vibration in helicopters is a function of the basic propulsion system and the aerodynamic properties of rotary wings, vibration is likely to remain a problem in the future.

Reflection of lights from the H-3 helicopter center console on the middle windscreen has led to disorientation when reflected cockpit lights were mistaken as light sources outside the aircraft at night.

Variation in the placement of the control stick in different aircraft can also cause disorientation during IFR conditions. For example, a number of older aircraft have had the cyclic control stick displaced from the midline in such a manner that, when the aircraft is flying straight and level, the stick may be as much as 1 to 2 inches off-center, rather than in the neutral center position. Holding the stick off-center, the pilot may get the sensation that he is banked, when he may in fact be 'wings level.' In IFR

Table V

Additional Helicopter Characteristics Noted as Contributory to Disorientation

| |
|---|
| 1. Excessive translational lift vibration |
| 2. Hover not level |
| 3. Reflection of anti-collision lights |
| 4. Vibration dampeners on instrument panel inadequate, allow blurring of instruments |
| 5. Light from middle console reflects on middle windscreen |
| 6. Cyclic stick not in center neutral position in level flight |

Table VI

Measures Reported by Aviators Which Effectively Counteract Disorientation

| |
|---|
| 1. Believe the gages and develop an effective instrument scan. |
| 2. Communicate; at first suspicion of disorientation, let the second pilot know. |
| 3. Avoid sudden or extreme head movements. |
| 4. When disorientation occurs, fly straight and level and increase forward airspeed. |
| 5. Learn to disregard physical sensations. |
| 6. In weather, turn off the forward rotator beacon. |
| 7. "Talk-yourself" through the instrument scan. |
| 8. Always fly with a trimmed stick (i.e., aircraft flies level with stick neutralized). |
| 9. Shift vision to ground (other pilot in control). |
| 10. Cross-check instruments. |
| 11. Transition to instruments <u>early</u> in deteriorating weather. |
| 12. If in hover, depart hover, and increase forward airspeed. |
| 13. Upon entry into a cloud bank, turn 180 degrees unless under positive control. |
| 14. Put in small control corrections when IFR. |

conditions, this may disorient the pilot, who must continually refer to the attitude gyro to ascertain his true attitude.

As noted in Table I, artificial horizons may lead to disorientation in IFR conditions. Sloping cloud banks and ground light patterns have been known to cause aviators to assume unusual flight attitudes. Figure 1 illustrates another situation, described by one respondent, in which a false horizon illusion may occur. In the cockpits of several different helicopter types, the instrument glare shield sloping over the attitude gyro may be unconsciously taken as the horizon in IFR conditions, making it appear that the attitude gyro is indicating a banked angle. This phenomenon may be contributory to the following incidents:

> Case 60. H-1, night, ground controlled approach, 30 hours. "About halfway down the glide slope, I experienced extreme difficulty in holding the aircraft level. The gyro didn't look right to me...when the gyro read level I felt we were in the bank. I had to turn control of the aircraft to my instructor."

> Case 58. H-1, simulated instrument flight, day, 50 hours. "We were just doing some practice banks and after rolling out I would continue to let one wing fall through. I knew I was in a turn, but no matter how hard I concentrated on keeping it level by the gyro, I continually let it drift between 5-10$^{o}$ angle of bank...(Under an instrument hood) I couldn't see the horizon...but could see thru the chin bubble...the cloud layer below."

Both cases above occurred in the Training Command in student helicopter pilots, where the curriculum includes flight training in H-1 helicopters. This source of illusion may be averted by removing the attitude gyro from close proximity to the sloping glare shield. It has been experienced and described by experienced instrument rated aviators in several types of helicopters.

## DISCUSSION

The types of disorientation to which the helicopter pilot is subject are, for the most part, similar to those reported in fixed-wing aircraft. However, it becomes evident after interviewing helicopter pilots that there are some types of disorientation which are peculiar to rotary-wing aircraft; i.e., some types of disorientation are most apt to occur in the helicopter's flight envelope, at low altitudes and slow airspeeds, or in a hover. Not only is the helicopter capable of roll, pitch, and yaw movements (i.e., rotational acceleration about the x-, y-, and z-axes) like conventional aircraft, but in a controlled hover, it is also capable of linear acceleration along the three axes. Thus, the pilot in a hover experiences a mixture of vestibular and proprioceptive stimuli which may be more difficult to interpret than those experienced in fixed-wing aircraft.

Comments obtained from the questionnaires indicated that, with minimum visual cues, forward ($+G_x$) acceleration is less conducive to disorientation than backward

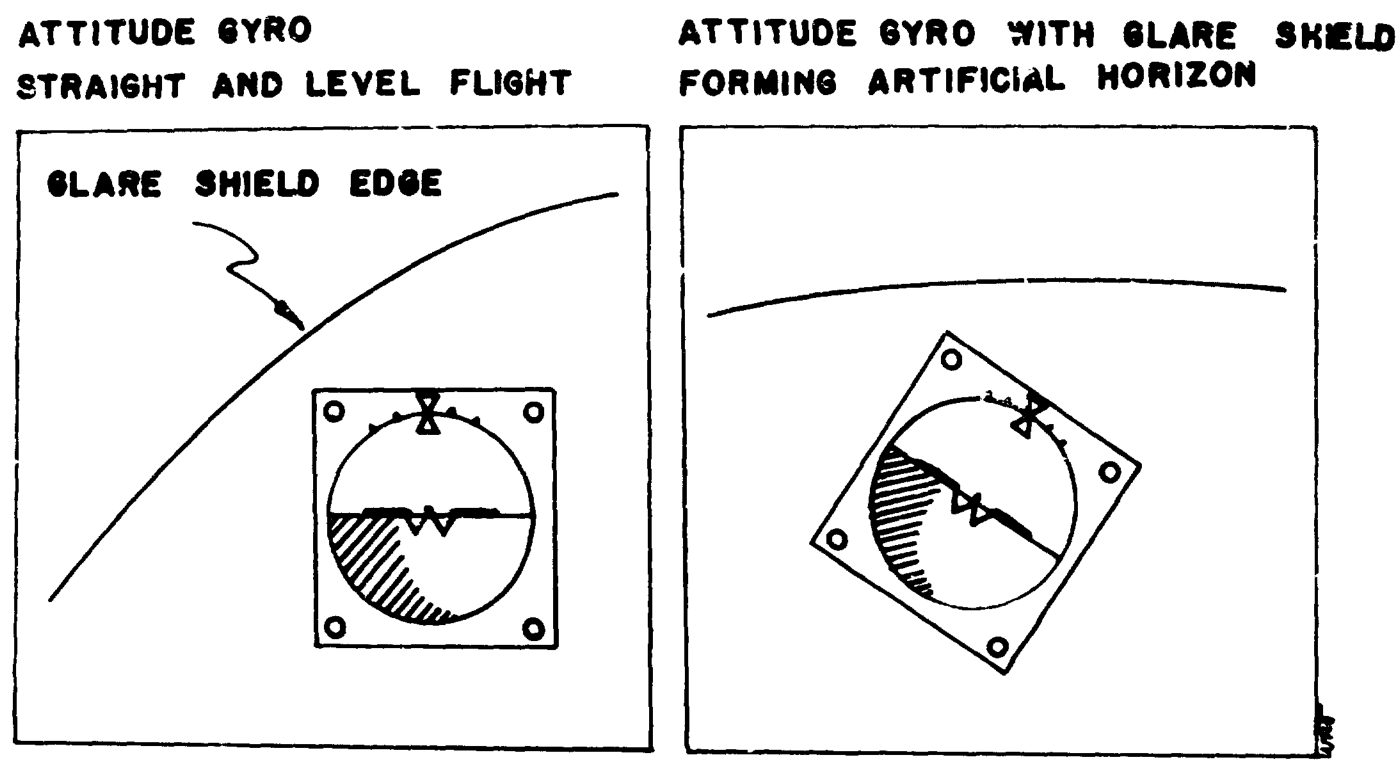


Figure 1

Illustrating a potential false horizon illusion produced by the instrument glare shield

($-G_x$), lateral ($+G_y$,$-G_y$), or vertical ($+G_z$,$-G_z$) acceleration. In fact, a common maneuver employed by helicopter pilots when disoriented is increasing forward airspeed and flying straight and level long enough to regain spatial orientation. It is not surprising, then, that the sensation of backward ($-G_x$) motion, especially in a night low altitude hover over water, is so disorienting. This sensation of "backing down" usually results in incorrect control input which leads to unusual aircraft attitudes.

From analysis of questionnaire responses, as well as from pilot interviews, it is evident that helicopter pilots are well sensitized to the hazards of night sonar dipping missions, and some measure of anxiety is almost always manifested, even in experienced aircrews, prior to and during night dipping exercises. To what extent this observed apprehension influences disorientation is an open question. Several reported experiments (8,11) indicate low sensitivity and dynamic perceptual inaccuracy to accelerations which are colinear with gravity. Although not generally understood, these perceptual deficiencies to vertical linear acceleration may contribute to the observed levels of apprehension associated with low altitude maneuvers.

Most germane to dealing with disorientation in rotary-wing aircraft is the helicopter's basic instability and its characteristic low altitude flight. The latter condition provides little time for recovery while the former means that recovery must be actively accomplished by the pilot. The classical method of counteracting disorientation has been to believe the gages and maintain a methodical scan of all flight instruments. In fact, 97 percent of the aviators questioned specifically mentioned this method of of self-discipline to avoid and counteract disorientation. Of all methods reported by aviators as effective in combating disorientation (Table VI), only two seem particularly pertinent in helicopters: turning off the forward rotator beacon, and departing hover and increasing forward airspeed. It appears, then, that methods employed by helicopter pilots to avoid disorientation do not differ greatly from those employed by fixed wing aviators. It is also apparent that procedures listed in Table VI to counteract disorientation are not always employed to their full advantage by most aviators. Awareness of these factors should be insured at the basic training level as well as at the operational squadron level.

With three out of four pilots reporting disorientation episodes related to reflection of the anti-collision beacon in weather, it is felt that the location of the beacon in helicopters should be moved aft, away from the cockpit. In H-3 helicopters and other helicopter types, the beacon is located directly beneath the cockpit. Relocating the beacon aft would substantially reduce the intensity of the reflection, although it will not completely eliminate it.

The increased use of helicopters as complex ASW systems has imposed an appreciable workload on the pilots. Operating a multisensored aircraft engaged in detection, tracking, and attack of submarines, the pilot's instrument scan and attention is affected adversely as the number of assigned auxiliary tasks increases. In fixed wing aircraft with similar multisensored systems, the problem of task saturation has been met successfully by addition of specialized crew members, relieving the workload on the pilots.

Late model helicopters, such as the SH-3H, may similarly require additional crew members as more complex ASW avionics are added.

The incorporation of new avionics systems in an aircraft necessitates the addition of instrumentation which must be displayed within the pilot's field of vision and manual reach. This presents a problem in cockpit design which often results in the placement of gages behind, above, and below the pilot. Review of disorientation narratives strongly suggests that the head motion required to monitor these additional instruments may bear a direct relationship to the frequency of disorientation. Although helicopter pilots are not subject to high g-forces in conventional flight, it does appear that the combination of mild g-forces (less than 1.5 g) and extreme head movements has a deleterious effect on spatial orientation. Specific recommendations from pilots should be considered concerning combining flight instruments into flight director systems which would reduce the area of instrument scan, minimize head movements, and perhaps provide "command" information to the pilot during IFR hover at low altitude rather than the present display of "raw" data which is provided in present helicopter cockpits.

A potentially effective countermeasure against the blurring of vision for cockpit instruments during critical flight movements may be a temporary increase of luminance level which improves vision when there is relative vibratory motion between the eye and flight instruments (cf. 6) and which may be a serendipitous countermeasure against other forms of disorientation (10). However, this suggested countermeasure should be investigated in helicopters for both positive and negative effects before it is regarded as a practical recommendation.

## SUMMARY AND RECOMMENDATIONS

A survey conducted among naval helicopter pilots to explore the incidence and type of disorientation experience in operations at sea indicates a number of disorientation problems. A high percentage of naval aviators experienced disorientation while in low altitude hovers at sea in IFR conditions, and at night. Factors which contribute to disorientation in this setting include relative motion illusion and somatic sensations while in the hover configuration. Disorientation was also frequently reported during approaches and take-offs from aviation ships at night. The nature of many helicopter missions, e.g., night search and rescue operations, may mean that the helicopter pilot is involved in situations requiring shifts between IFR and VFR more frequently than the fixed wing pilot. Such shifts potentiate disorientation. Measures reported by helicopter pilots as effective in counteracting disorientation do not vary significantly from measures reported by fixed wing aviators to avoid disorientation. It is recommended that all known disorientation countermeasures be stressed in basic and refresher helicopter training, with special emphasis on those situations which are particularly troublesome in helicopters.

The importance of the anti-collision beacon as a disorienting factor is again evident, confirming previous studies, and it is recommended strongly that the dorsal and ventral beacons be displaced aft, away from the cockpit.

Rotary wing as well as fixed wing pilots should recognize and be especially alert in those phases of flight where disorientation is most likely to occur, and should learn to recognize and disregard visual and vestibular phenomena which may lead to disorientation. The frequency of disorientation in low altitude hovers, especially over water, indicates the need to continuously maintain instrument proficiency in this configuration both in training and operational squadrons. The fact that man seems to be particularly insensitive to vertical accelerations, i.e., accelerations aligned with gravity, is especially relevant information for helicopter pilots.

Characteristics of helicopters which are recognized as playing a role in disorientation include the helicopter's capacity for both angular and linear acceleration along three axes and occasional high vibration levels. The effect of vibration on the vestibular and proprioceptive senses chronically and acutely in certain phases of flight may be causally related to disorientation and requires further study. Vibration can degrade visual acuity for instruments at critical times in some helicopter operations. Increasing the luminance level of the instruments may be a helpful countermeasure for this problem, but this requires field study. The helicopter's instability of flight and its characteristic low altitude flight operations mean that the pilot must actively accomplish recovery and that he frequently has little time to do so. Changes in cockpit instrumentation which may reduce the frequency of disorientation include reducing the area of the instrument scan by combining flight instruments and providing command information, thereby reducing both data processing time and the amount of head motion required to monitor the instruments. Also, removing the attitude gyro from beneath sloping glare shields and incorporating a flight director system in helicopters may reduce the frequency of disorientation experienced by helicopter pilots.

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APPENDIX A

Disorientation Questionnaire*

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*Condensed from original for space-saving purposes. Original questionnaire allowed ample space for responses.

DISORIENTATION QUESTIONNAIRE

PURPOSE

The following questionnaire was developed to give us an idea of the frequency and type of disorientation experienced by helo pilots in present day aircraft.

There is a lack of current information on disorientation in the naval helo community and such information may be beneficial for continued safe operations. We are particularly interested in disorientation phenomena occurring during operations at sea, as this area has been least explored.

The questionnaire is strictly confidential. Do not write your name on any form. No aviator will be identified by name or squadron.

A concerned effort will be made to give you some feedback on the results of this study.

Your cooperation is greatly appreciated.

F. R. TORMES
LCDR MC USNR
FLIGHT SURGEON, HS-15

W. PETTIT
LCDR MC USNR
FLIGHT SURGEON
COMHELAS WING I

SOME GROUND RULES

For the sake of uniformity, let DISORIENTATION mean an incorrect mental or "seat of your pants" impression of the attitude, position or movement of the pilot and/or aircraft relative to the horizon, or other stable reference. For the purposes of this discussion, consider the flight deck of a moving ship a "stable reference."

Let VERTIGO mean a sensation that the pilot or environment is spinning. For the purposes of this discussion do NOT consider navigational error or "being lost" as disorientation.

Gage the degree of disorientation subjectively as follows:

MILD--you felt disoriented and uncomfortable but always felt in control of the A/C.

MODERATE--you felt disoriented and concerned and there may have been an adverse effect on A/C control.

SEVERE--you felt disoriented, mentally stressed and/or there was definite interference with A/C control.

ALL questions apply ONLY to flight conditions in helicopters in which you were pilot or co-pilot. Include experiences in the training command.

QUESTIONS

1. Total # hours to date ______ (see note below)
   Total # helo hours ______
   Total # instrument hours (actual and simulated) ______

   Note: You may approximate to nearest 100.

2. In your experience, have any of the following factors or situations been associated with, or led to, disorientation? (Yes/No - if any item led to SEVERE disorientation, write an X in the given space. If any item led to disorientation more than once, approximate how often.)

| | YES | NO | S | # |
|---|---|---|---|---|
| Reflection of lights on windshield | ____ | ____ | ____ | ____ |
| Reflection of anti-collision lights on clouds, fog, etc., outside cockpit | ____ | ____ | ____ | ____ |
| Awareness of flicker of rotors | ____ | ____ | ____ | ____ |
| T/O or landing in strong crosswind | ____ | ____ | ____ | ____ |
| T/O from CVA, LPH or other ship | ____ | ____ | ____ | ____ |
| Misjudgment of altitude following T/O from CVA, LPH, or other ship | ____ | ____ | ____ | ____ |
| Landing on CVA, LPH, or other ship, day | ____ | ____ | ____ | ____ |
| Landing on CVA, LPH, or other ship, night | ____ | ____ | ____ | ____ |
| Low altitude hover over land | ____ | ____ | ____ | ____ |
| Low altitude hover over water, day | ____ | ____ | ____ | ____ |
| Low altitude hover over water, night | ____ | ____ | ____ | ____ |
| Night transition from hover over flight deck to forward flight | ____ | ____ | ____ | ____ |
| HIFR from DE, DLG or other ship | ____ | ____ | ____ | ____ |
| Misinterpretation of relative position or movement of ship during night approach | ____ | ____ | ____ | ____ |

| | | | | |
|---|---|---|---|---|
| Formation flying, day | | | | |
| Formation flying, night | | | | |
| Misled by faulty instrument | | | | |
| Inability to read instruments due to vibration | | | | |
| Head-movement while in turn or bank | | | | |
| Misperception of true horizon due to cloud bank | | | | |
| Misperception of true horizon due to ground light pattern | | | | |
| Sensation of not being straight and level after bank and turn ("the leans") | | | | |
| Transitioning from VFR to IFR or vice-versa | | | | |
| Going IFR due dust, snow, etc., in low hover | | | | |
| Distraction by aircraft malfunction | | | | |
| Fatigue | | | | |
| Vibration | | | | |
| Symptoms of cold or flu | | | | |
| Self-treatment with over-the-counter medication | | | | |
| Flying a specific type mission; mention mission type | | | | |
| Flying a specific type aircraft; mention type A/C | | | | |
| Other factors or conditions not covered above (Please briefly describe below and on the next page.) | | | | |

3. Now estimate how many times you have experienced severe disorientation. ____

Moderate?______ Mild?______

4. Check here if you have NEVER experienced any degree of disorientation. ____

5. Have you been involved in an accident or incident as a consequence of disorientation? ____

6. Have you ever been in a situation in which BOTH pilots were disoriented? ____

7. Please relate in detail your most "memorable" episodes of disorientation. (As pilot, co-pilot, in helo)

   Please make reference to helo type, weather factors, day/night, and degree and duration of disorientation, and approximate your total number of helo hours at the time.

8. Do you have any suggestion as to how another aviator could avoid disorientation in a similar situation?

9. How do you counteract disorientation?

10. It has been suggested that helos should be equipped with additional instrumentation, i.e., monitors of sideways and backward drift, visual displays, etc., to help avoid disorientation. Do you feel this would be helpful and exactly what changes in cockpit instrumentation would you recommend?

11. Have you noted any idiosyncracies of design in any specific type helo which "set you up" for disorientation? Do you think it could be eliminated?